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The effect of using liquid organic fertilizer arenga palm [*Arenga Pinnata* (Wurmb) Merr] on the growth rate of robusta coffee (*Coffea Canephora* L.)

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Abstract

This study was a field experiment conducted in the summer to evaluate the effects of Liquid Organic Fertilizer (LOF) derived from oil palm sap on the growth of robusta coffee seedlings as an alternative to chemical fertilizers. The method was designed using a single-factor Randomized Block Design (RBD) with five treatments, including, plant height, number of leaves, leaf width, stem diameter and root volume. Observations were conducted from 3 weeks to 9 weeks after planting. The results showed that the administration of oil palm sap (LOF) at a dose of 80 mL/L (M4) had significant positive impact on the growth of robusta coffee seedlings. The average plant height was recorded at 25.46 cm, the number of leaves at 10.50, the average leaf width at 5.44 cm, the stem diameter at 4.42 cm and the root volume at 6.2 mm. This study is the first to examine the use of oil palm sap LOF on robusta coffee seedlings and has shown substantial results with doses ranging from 20-80 mL/polybag. This study highlights the potential of using sustainable organic fertilizers, such as oil palm sap LOF, to support the growth of robusta coffee plants.

Keywords

arenga palm; fertilizer; liquid; organic and robusta coffee

Introduction

Coffee is a vital plantation crop and is significant source of foreign exchange for many countries . It is a perennial plant belonging to the genus *Coffea* in the Rubiaceae family (1). It thrives in tropical and subtropical areas. Factors such as genetics, environment and even land maintenance, influence coffee yields (2). Among the environmental factors, low soil fertility due to minimal availability of fertilizer, poses a significant challenge to coffee production. Fertilizer are a critical input in agricultural practices and must be consistently available to ensure sustained productivity.

The use of organic fertilizers offers a sustainable solution to declining soil fertility and enhances crop production in the long term (3). Plant nutrition is one of the most important factors in determining agricultural productivity and quality. Nutrient levels in the soil directly affect the quality of the harvest, while inappropriate use of chemical fertilizers can degrade soil health and harm the surrounding environments (4). Organic materials, when decomposed into nutrients, contribute to soil health and are particularly beneficial for crops like coffee. Organic fertilizers function to maintain the physical, chemical and biological properties of the soil, which are beneficial for healthy plant growth. Common organic fertilizers include manure, compost and plant residues (5).

By slowly releasing nutrients into the soil, organic fertilizers maintain the nutrient balance required for optimal plant growth. They also serve as a valuable energy source for soil bacteria, which further enhance plant growth and soil quality (6). The accumulation of soil organic matter improves the physical and chemical quality of the soil and meets the nutritional needs of many beneficial soil microorganisms (7). Additionally, organic fertilizers help reduce metal toxicity in the rhizosphere (8).

LOF offers an effective alternative, as they can be directly applied to plant tissue, improving nutrient absorption. Soil bacteria associated with LOFs can mineralize organic phosphorus or solubilize inorganic phosphorus, making bioavailable to the plant system (9). This targeted application increases the economic value of LOFs compared to solid fertilizers and their effectiveness can vary depending on plant growth rates and development (10).

A specific LOF formulation, derived from *Arenga pinnata* (Wurmb) MERR (aren palm) sap mixed with shrimp shell flour and fermented for 42 days, has been found to contain 1.37 % Nitrogen (N), 0.25 % Phosphorus (P) and 8.07 % Potassium (K) (11). This study aimed to evaluate the growth of robusta coffee seedlings using aren sap as a liquid organic fertilizer, offering a sustainable and effective approach to improving coffee cultivation.

Materials and Methods

This research was conducted in the experimental garden of the Mujahidin Tolioli Indonesia College over a period of 3 months, from March 12 to June 12. The materials used included basic chicken manure fertilizer, LOF derived from palm sap and 20 x 20 cm polybags. The polybag media was filled with soil that had been loosened, cleaned and air-dried for 2 days. The soil was then mixed with manure and weighed to ensure accurate measurements. Each polybags was filled with 1.5 kg of soil and goat manure (500 g).

For making palm sap fertilizer, the ingredients consist of palm sap (1400 mL), coconut water (500 mL), rice washing water (400 mL), brown sugar (400 g) and distilled water (700 mL). These components were placed in a sealed container and fermented for 42 days. To inactivate microorganisms in the LOF, 25 g of gambier or 10 ccs of formalin was added to the fermented liquid. The resulting liquid was then used at the specific doses or concentrations for testing . The experimental fertilizer was applied three times during the study: 3 Weeks After Planting (WAP), 6 WAP and 9 WAP (Fig. 1).

This study used a single-factor RBD consisting of 5 treatments, each repeated 4 times with 4 polybags per repetition, resulting in a total of 80 plant units. All plants served as sample plants for the experiment.The LOF treatments were as follows:

M0 = No LOF Nira Aren (control)

M1 = Palm Nira liquid organic fertilizer 20 mL/L of water

M2 = Palm Nira liquid organic fertilizer 40 mL/L of water

M3 = Palm Nira liquid organic fertilizer 60 mL/L of water

M4 = Palm Nira liquid organic fertilizer 80 mL/L of water

Data collected during the experiment were analyzed using analysis of variance (ANOVA). If a significant or highly significant effect was observed, a follow-up Honest Significant Difference (HSD) test at the 5 % and 1 % levels was performed. Observations were conducted every three weeks, starting at 3 WAP and continuing at 6 WAP and 9 WAP. The parameters measured included the number of leaves, leaf width (measured with a ruler on fully expanded leaves), stem diameter (measured with a caliper) and root volume (measured at the conclusion of the study at 9 WAP).

Results and Discussion

Plant heights

The observed growth is triggered by the NPK nutrient content and hormone content contained in the LOF palm sap. This can be proven by comparing the growth of control plants and treatment plants. Nitrogen plays a key role in prompting the growth of apical meristems, leading to increased plants height, a function similar to the role of auxin and gibberellin hormones found in LOF palm sap (12). Plants exhibit a rapid respond to liquid organic fertilizers, as N availability is significantly influenced by climatic conditions and cannot be synthesized from parent material as stated by (13). Since the concentration of carbon, nitrogen and phosphorus in leaves is much higher than in the soil, consistent fertilization is needed in this setting (Table 1 & Fig. 2) (14).

The primary growth and height of coffee plants are significantly influenced by the use of organic fertilizers. Nitrogen, as an essential component of chlorophyll, proteins, hormones and enzymes has a profound effect on plant height (15). Adequate nitrogen intake promotes beneficial outcomes for plant growth, as it serves as a critical building block in metabolic processes (16). Furthermore, an optimal nitrogen supply has been shown to significantly impact photosynthetic rate, stomatal conductance, root biomass and root distribution(17).

Number of leaves

The results showed that the number of leaves on Robusta coffee seedlings at 3, 6 and 9 WAP was greatly influenced by the injection of palm sap at different doses. From 3 to 9 weeks after planting (WAP), the average number of new leaves produced under each treatment is illustrated in Fig. 3, while Table 2 summarizes the average number of leaves produced by each treatment.

As shown in Table 2 the M4 treatment (80 mL) yielded the highest average number of leaves compared to the M1 (20 mL), M2 (40 mL) and M3 (60 mL) treatments at 6th and 9th weeks, with an average of 10.50 leaves. The application of palm sap with a higher LOF concentration stimulated the plants to produce more oxygen and increased their photosynthesis rate (18). Organic fertilizers have been reported to increase plant growth, leaf number and chlorophyll levels. A higher number of leaves corresponds to an increased photosynthetic rate, whereas fewer leaves result in slower photosynthesis (19). The application of liquid organic fertilizers should be adjusted to their specific needs of the plants to promote faster leaf production.

Table 1. The average height of robusta coffee seedlings aged 3 WAP, 6 WAP and 9 WAP

LOF Nira Aren	Plant height (cm)		
	3 WAP	6 WAP	9 WAP
0	17.38 a	18.47 a	20.05 a
20 mL/L	20.14 b	21.47 b	24.08 ab
40 mL/L	18.64 ab	21.24 ab	24.03 ab
60 mL/L	19.26 ab	20.84 ab	24.21 ab
80 mL/L	18.81 ab	21.03 ab	25.46 b

Source: Prepared by the author (2024)

Table 2. The average number of leaves of robusta coffee seedlings aged 3 WAP, 6 WAP and 9 WAP

LOF Nira Aren	Number of leaves (strands)		
	3 WAP	6 WAP	9 WAP
0	7.06 a	7.38 a	8.81 a
20 mL/L	8.81 b	8.81 ab	9.94 ab
40 mL/L	8.94 ab	8.94 ab	10.25 ab
60 mL/L	9.25 ab	8.56 ab	9.56 ab
80 mL/L	9.75 ab	9.06 ab	10.50 b

Source: Prepared by the author (2024)

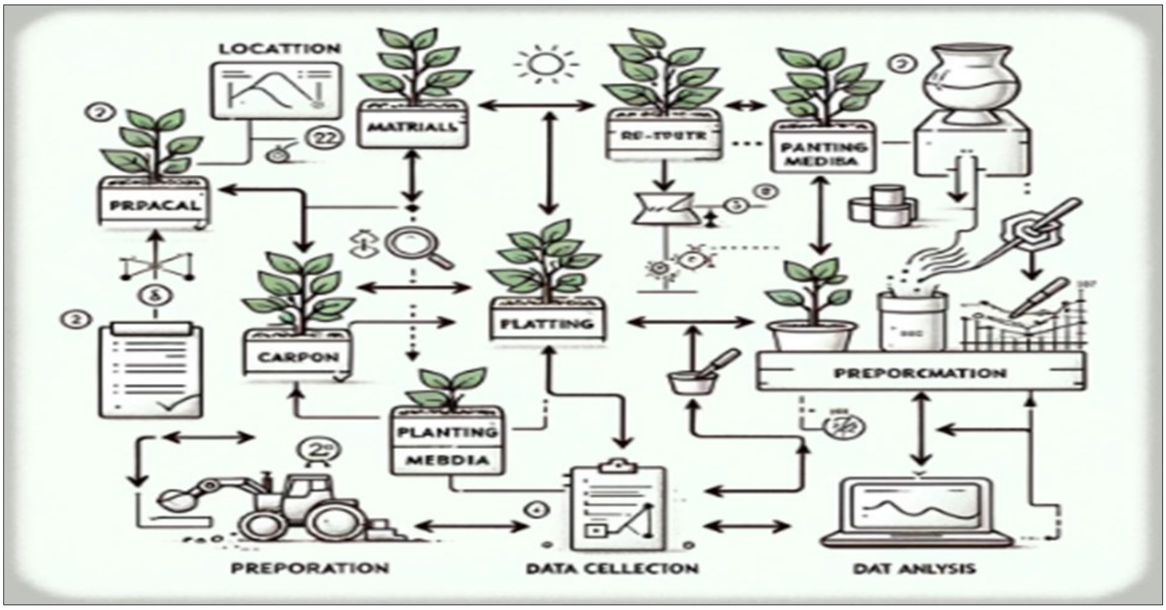

Fig. 1. Research methodology flowchart.

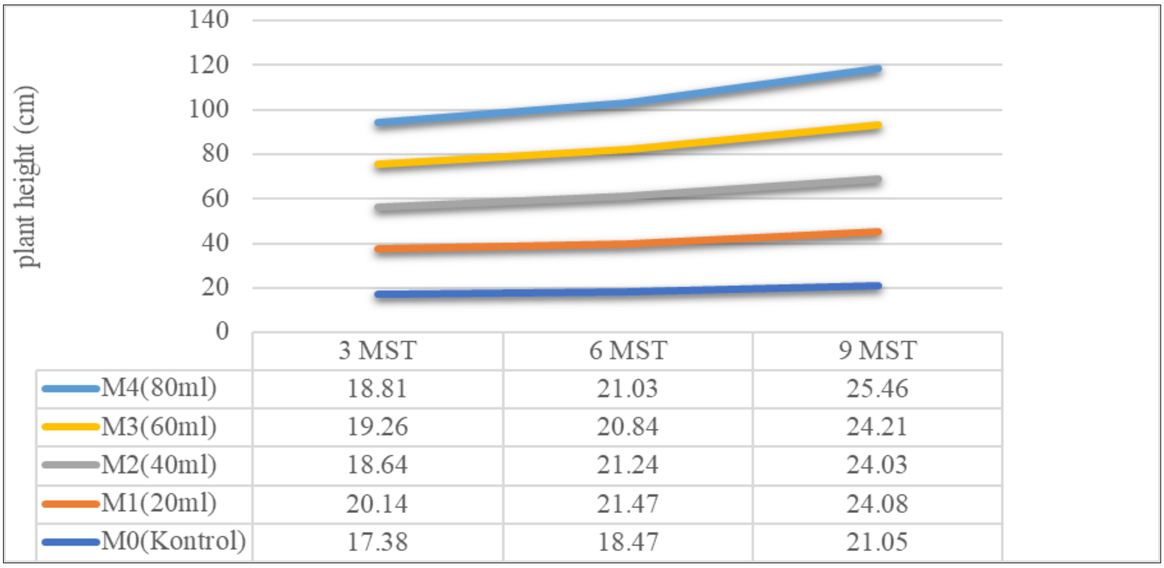

Fig. 2. Average robusta coffee plant height due to LOF arenga palm.

Recent study illustrates that, nitrogen is one of the most important nutrients for plant development and growth (20). It is difficult to obtain N and other nutrients from inorganic sources in the soil. In photosynthesis, K helps maintain the stability of the electrical charge near ATP synthase, as well as supporting fruit and root development and enhancing sugar storage (21).

Leaf area

Different doses of palm sap affect the leaf width at the ages of 3 WAP, 6 WAP, and 9 WAP, more clearly can be seen in Fig. 4. The results of the variance analysis can be seen in Table 3.

As shown in Table 3, the M1 treatment (20 mL) showed good results at 9th week of WAP, achieving an average leaf width of 5.44 cm, compared to M2 (40 mL), M3 (60 mL) and M4 (80 mL) treatments. However, at 3 WAP, with the M4 treatment (80 mL) demonstrated superior performance, with an average leaf width of 3.80 cm, compared to M1 (20 mL), M2 (40 mL) and M3 (60 mL). At 6 WAP, the M1, M3 and M4 treatments did not show maximum leaf width, whereas the M2 treatment yielded better results, with an average leaf width of 4.54 cm.

The LOF of aren sap effectively supplied the N required for plant development, with an N content of 1.37 ppm in the organic aren sap fertilizer (22). Optimal nitrogen

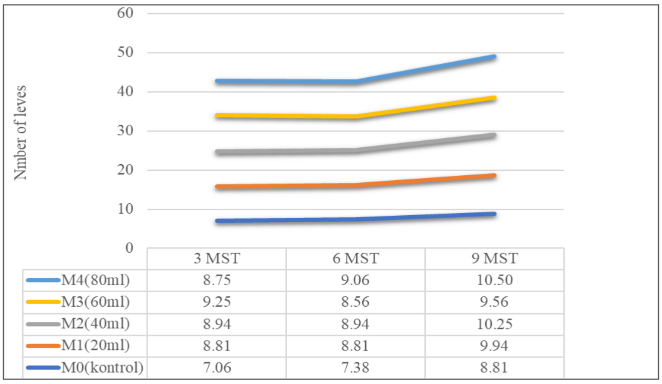

Fig. 3. Average number of leaves of robusta coffee seeds due to giving LOF arenga palm.

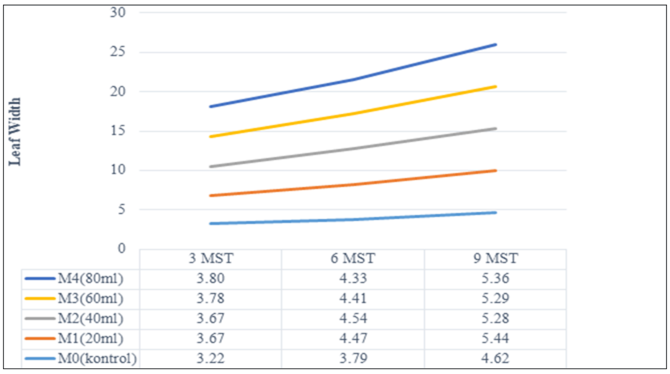

Fig. 4. Average leaf width of robusta coffee beans due to LOF arenga palm.

Table 3. Average leaf area of robusta coffee seedlings aged 3 WAP, 6 WAP and 9 WAP

LOF Nira Aren	Leaf area (cm)		
	3 WAP	**6 WAP**	**9 WAP**
0	3.22 a	3.79 a	4.62 a
20 mL/L	3.67 ab	4.47 b	5.44 b
40 mL/L	3.67 ab	4.54 b	5.28 b
60 mL/L	3.78 ab	4.41 ab	5.29 b
80 mL/L	3.86 b	4.33 ab	5.36 b

Source: Prepared by the author (2024)

levels have been shown to significantly enhance the rate of photosynthesis, stomatal conductance, root weight and root spread. Liquid fertilizer, which covers more than 80 % of the total N application, encourage the development of chlorophyll, a green pigment in leaves that is essential for photosynthesis. Supporting this observation, it has been reported that sufficient nitrogen availability promotes leaf growth and expansion, increasing the surface area available for photosynthesis. Conversely, inadequate nitrogen intake can impede the growth of coffee plants..

The availability of nutrients including nitrogen, phosphorus and potassium significantly influences the process of new cell formations. Phosphorus plays a role in activating enzymes needed for photosynthesis, while potassium contributes to the growth of meristematic tissues, directly affecting leaf size. Additionally, potassium helps regulate plant water consumption by modulating the opening and closing of stomata, facilitating transpiration and cooling the plant. Under high-light conditions, plant leaves tend to shrink, thicken and increase in density, which is accompanied by a reduction in the number of stomata, cuticle layers and cell wall thickness, as well as an enlargement of intercellular gaps.

Rod diameter

Analysis of variance revealed that dosing with palm sap at different LOF levels had no influence on the stem diameter of robusta coffee seedlings at 3 WAP. However, a notable effect was observed at 6 and 9 WAP. Fig. 5 displays the average stem diameter expansion of seedlings across treatments from 3 to 9 WAP.

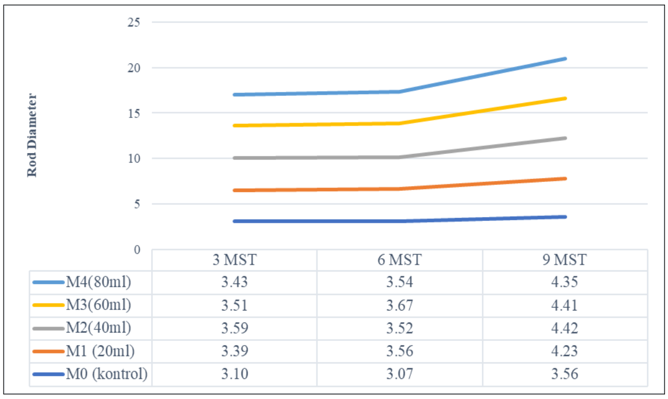

Fig. 5. Average stem diameter of robusta coffee beans due to LOF arenga palm.

Table 4 shows that the M2 treatment (40 mL) exhibited favorable results compared to the M1 (20 mL), M3 (60 mL), M4 (80 mL) and M0 (control) treatments at both 3rd and 9th WAP. The average stem diameter under the M2 treatment at 9 WAP was recorded as 4.41 mm. The application of palm sap at this concentration effectively provided the essential N, P and K nutrients required by coffee seedlings. These nutrients play a crucial role in stimulating vegetative growth, including increasing stem diameter. The addition of NPK nutrients ensures adequate nutrition for plant growth and supports critical physiological processes, such as cell division and elongation, ultimately contributing to the enlargement of stem diameter (23).

Nitrogen is the main nutrient needed for vegetative plant growth, including leaves, stems and roots. Enhanced nitrogen absorption by plants leads to an increased concentration of nitrogen in leaves, which supports photosynthesis and promotes overall plant growth. This includes achieving taller plants with larger stem diameters (24).

Root volume

The use of various doses of palm sap significantly affected the root volume of robusta coffee seedlings (Fig. 6) while Table 5 shows highlights the average root volume produced. The M4 treatment (80 mL/L) demonstrated the most favorable outcome, yielding an average root volume of 6.20 mm, surpassing the results of treatments M1 (20 mL/L), M2 (40 mL/L) and M3 (60 mL/L). Conversely, the control treatment (M0) recorded the lowest root volume, averaging 4.68 mm.Enhancing root and shoot development is closely linked to the applications of balanced liquid organic fertilizer. These fertilizers contribute to increasing soil organic matter (25). Robusta coffee plants, in particular, benefit greatly from the NPK nutrients present in liquid organic fertilizer, which promotes healthy vegetative growth. Plants absorb nutrients through mechanisms such as roots, mass flow and diffusion.

LOF provide essential nutrients, including nitrogen, phosphorus and potassium. Nitrogen serves as a critical building block for protein synthesis, phosphorus stimulates the

Table 4. Average stem diameter of robusta coffee seedlings aged 3 WAP, 6 WAP and 9 WAP

LOF Nira Aren	Stem diameter(mm)		
	3 MST	6 MST	9 MST
0	3.10 a	3.07 a	3.56 a
20 mL/L	3,39 a	3.56 ab	4.23 ab
40 mL/L	3.59 a	3.52 ab	4.24 ab
60 mL/L	3.51 a	3.67 b	4.41 b
80 mL/L	3.43 a	3.54 ab	4.35 b

Source: Prepared by the author (2024)

Table 5. Average root volume of Robusta coffee seedlings aged 9 WAP

LOF Nira Aren	Root volume
	9 WAP
0	4.68 a
20 mL/L	5.30 ab
40 mL/L	5.35 ab
60 mL/L	5.35 ab
80 mL/L	6.20 b

Source: Prepared by the author (2024)

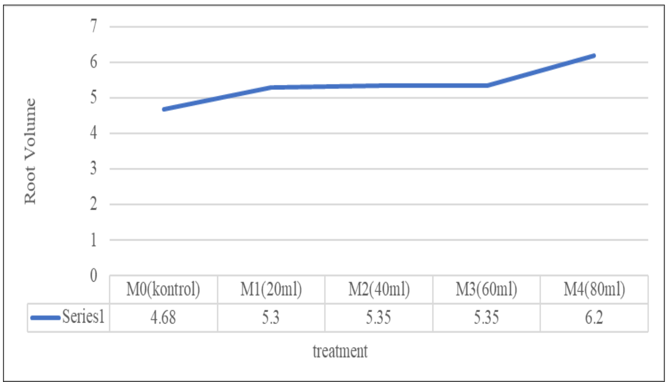

Fig. 6. Average volume of robusta coffee roots due to LOF arenga palm.

proliferation of meristematic tissue and potassium encourages root development (25). The absorption of potassium has a profound impact on root length, surface area, volume and the number of root tips (26, 27). Given that palm sap fertilizer contains a notably high potassium concentration of 8.07 %, the application of an 80 mL/L dose significantly enhances root growth and development.

Conclusion

Palm sap LOF, derived from fermented sap water and enriched with other organic materials to increase its nutritional value, was applied in doses ranging from 20 mL to 80 mL per polybag. This fertilizer has proven to be highly effective in promoting the growth of robusta coffee plant seedlings, as evidenced by various growth parameters including plant height, number of leaves, leaf area, stem diameter and root volume.

In conclusion, the main findings of this study indicate that the application of palm sap liquid organic fertilizer significantly improves the growth and development of robusta coffee seedlings. Unlike other studies that often focus on synthetic fertilizers or organic fertilizers with lower nutrient content, this research underscores the superior benefits of using palm sap-based organic fertilizer. These results have important implications for farmers and agricultural practitioners, suggesting that the adoption of this method could provide a sustainable and nutrient-efficient alternative to conventional farming practices, promoting healthier plant growth and improved agricultural outcomes.

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Compliance with Ethical Standards

Conflict of interest: The authors state that they have no conflicts of interest.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used grammarly in order to check and improve the grammer and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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